greatly improved facilities for the work of the college and station. At the Texas Agricultural College there is a new agricultural and horticultural building costing over $30,000, and at the Kansas Agricultural College an agricultural building of the same value. At the Oklahoma Agricultural College there are new chemistry and library and science buildings, and at the Virginia Agricultural College and the University of Tennessee new and commodious barns have been erected, each costing about $5,000. At the latter institution a dairy building has also been constructed. At the Agricultural College of the University of Minnesota a horticultural-botanical building costing $35,000 has been erected.

It is believed that the successful work of the experiment stations has been a large factor in arousing the attention of the public to the benefits of instruction as well as research in agriculture, and to the importance of equipping the agricultural colleges more amply and giving them increased funds for the extension of their work in both directions. It is well that this fact should be brought to the attention of legislators when appropriations for these institutions are being made. Funds are needed for the extension of investigations as well as for better equipment, and oftentimes a comparatively small sum added to the current revenue of the station will enable it materially to strengthen its work. This is so because the broad organization of our stations requires that a relatively large portion of the national funds must be expended for salaries and wages. This leaves so little for the general expenses of investigations that they can not as a rule be made very extensive. If it is desirable that particular investigations should be conducted on a somewhat extensive scale or in different localities, the State can often secure this desirable result by providing funds for these specific purposes. As regards the investigations which need to be carried on in different localities, it is, in our judgment, a much wiser policy to give the stations funds for such special investigations than to establish permanent substations, which have universally proved to be relatively expensive and unsatisfactory.

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*THE DEVELOPMENT OF THE EXACT NATURAL SCIENCES IN THE NINETEENTH CENTURY.**

THE lecture delivered by Van't Hoff, under the above title, although scarcely an hour in length, contains so much important material that a brief account of its contents cannot fail to be of interest to the readers of SCIENCE. The lecture deals only with the sciences of inanimate nature, and, therefore, does not touch any branch of the biological sciences.

Although the question of utility has had much to do with the development of many branches of science, yet the highest aim has not been reached in this way. The sciences have, then, been divided into *theoretical* and *applied.* And we must make the further division into the *general* and the *concrete* or *special* sciences.

The general sciences are dealt with first. These are divided into two classes. First, the *three fundamental mathematical sciences,* which center around the three fundamental conceptions of quantity, space and time. The science of quantity is analysis, including arithmetic, algebra and the higher analysis. The science of dimensions is geometry; while in mechanics, the science of force and movement, time enters as a factor. Second, the two *experimental natural sciences*—physics and chemistry.

Almost an unlimited amount has been accomplished in the nineteenth century in the field of the mathematical sciences. It is only necessary to mention such names

* Lecture delivered by Van't Hoff at the seventy-second meeting of the Society of German Men of Science and Physicians, in Aix-la-Chapelle.

as Abel, Cauchy, Gauss, Jacobi, Riemann, Weierstrass. The general laws of these sciences were established at the beginning of the century, and remain essentially unaltered. The great discovery for mechanics in the nineteenth century is the law of the conservation of work. Since this law lies at the very foundation of mechanics, it is of fundamental importance for the whole science. The discovery and development of this law belongs to the field of physics, yet it was not developed by physicists alone. Mayer was a physician, Joule a brewer, Colding an engineer, and Helmholtz was at that time a physiologist.

The influence of this law on mechanics was pointed out by Lagrange in two equations—the one for motion, the other for rest or equilibrium. In the light of the law that the amount of work cannot change, these two equations became relatively very simple. This law is as follows: *The total amount of work is unalterable.* It should be observed that work can have two forms, the form of movement (or kinetic energy), and the form where a weight moves a clock—where the capability of doing work is connected with the weight, therefore, with a force, (potential energy). The law should be expressed thus: *The sum of the two kinds of work is unalterable.*

We can then say, in general, of our three fundamental sciences, that at the close of the nineteenth century they rest on a foundation that is practically perfect.

If we now turn to the experimental sciences, physics and chemistry, we find that there is no sharp division between them. Recently a celebrated chemist said that Lavoisier and Bunsen were not chemists, but physicists, and to show what inherent connection exists between the two, Bunsen himself said '*a chemist who is not a physician is nothing.*'

The physicist has to do chiefly with the transformations of *force;* the chemist with the transformations of *matter.*

Turning now to physics, therefore, to the problem of the transformations of natural forces or corresponding work forms, the developments in the nineteenth century are closely connected with the fundamental conceptions that natural processes are to be referred to purely mechanical movements and forces. Since light, sound, heat, electricity and magnetism are only different forms of movement, the possibility exists of transforming these into one another. This is the first great advance in physics. It was Faraday especially who believed in the correlation of energy. This reciprocal transformation of work forms, of course, takes place in daily life in the steam engine, dynamo, etc., and from this energy heat and light can be reproduced.

The second great advance is, of course, the law of the conservation of energy, or of work, in terms of which the total amount of work remains unchanged.

A third important step was taken. If one form of work can be transformed into another and this transformation takes place quantitatively, then the question still remaining is, Which way will the transformations take place? This was answered by Carnot and Clausius in what has become the second law of thermodynamics. This is often formulated thus: Heat always flows from a warmer to a colder body. Helmholtz formulates it in terms of 'free work.'

We now consider the *last fundamental step* which has been taken—how *quickly* do transformations take place in nature? This brings us to the views in reference to the inner nature of natural processes—views which have been developed in the nineteenth century. As an example, let a local increase in pressure be produced in the air by, say, an explosion. This increase in pressure tends to equalize itself, and the excess of pressure moves through the air as

sound. From the assumption that sound is a wave movement in an elastic medium like air, Newton and Laplace calculated its velocity accurately as 330 meters per second.

That sound is a vibratory movement is not theory but fact. In other regions, however, we have only theories as to the nature of the phenomena. We have had to distinguish between matter and ether; the former consisting of very small, perfectly elastic parts, which are different for each element; the latter, a medium everywhere present, penetrating everything. The ether is the carrier of all radiation, as for example, light.

Let us trace the development of the views concerning light. According to Newton light was produced by light particles which moved with great velocity. The discovery of interference by Fresnel at the beginning of this century showed that light was a wave motion, as Huyghen's had supposed. The vibrations took place in the ether, and light moved with a velocity about one million times that of sound. In order to explain the phenomenon of polarization it was necessary to assume that the vibrations are transverse and not longitudinal.

The view that the ether is a simple elastic medium could not account for the relations between light, electricity and magnetism. Those substances which are the best conductors of electricity, as the metals, are opaque to light; while glass, which is transparent to light, does not conduct electricity. Relations such as these led Maxwell, Helmholtz and others to the assumption that the vibrations in the ether are of an electrical nature. This was the origin of the electromagnetic theory of light. In terms of this theory, light is only an electromagnetic vibration of the ether of very small period. The number of vibrations per second is about 400 billions for red and 800 billions for violet light. But there is still an infinite field for slower and also for more rapid vibrations, and here we meet with the greatest discoveries of the nineteenth century. The somewhat slower vibrations are heat rays; the somewhat more rapid are chemical rays; the still more rapid are the Röntgen rays, corresponding to the Helmholtz very rapid electromagnetic vibrations; while the very slow vibrations (about 100 million per second) are the Hertz waves. These electrical vibrations behave just like light, only they are invisible. They find application in wireless telegraphy.

The assumption is, therefore, plausible that light also is produced by electrical vibrations of the charged atoms or ions in the source of light. This is confirmed by the discovery of the Zeeman effect.

Let us now turn to chemistry. Substances like potassium and sodium, which at the beginning of the century were regarded as elementary, have been decomposed by Davy. The remaining elements have, however, maintained their elementary nature, and about 80 are now known. That an organic connection exists between the elements has been shown by Newlands, Lothar Meyer and Mendeleff. In terms of this relation new elements have been predicted and they have since been discovered by Locoq de Boisbaudran, Winkler and Nilson. These elements are, of course, gallium, germanium and scandium.

The *synthesis* of compounds has been carried very far indeed. The synthesis of urea by Wöhler broke down the distinction between the compounds prepared in nature and in the laboratory. And we can now prepare optically active substances in abundance. Synthesis has reached its climax in the preparation of the artificial dyes. Graebe and Liebermann have made alizarin. Baeyer has effected the synthesis of indigo. Ladenburg of the alkaloid coniine, while

Emil Fischer has effected the synthesis of grape sugar.

It now only remains to make artificially the enzymes and albumens. Up to the present these require the intervention of life.

The most careful quantitative study of the transformations of matter have shown that mass remains unchanged. A definite quantity of every element was, is, and will be. This recalls the law of the conservation of work, and is perhaps connected with it.

The atomic hypothesis, which was proposed by Dalton as a convenient means of explaining the laws of definite and multiple proportions, has been given new meaning by Avogadro, and Kekulé, in terms of valence, has shown how the atoms are united in the molecule. Stereochemistry has even thrown light on the arrangement of the atoms in space, and Mitscherlich has shown that there are relations between the external crystal form and the atomic composition and constitution of the molecules.

The chemistry of the nineteenth century is also characterized by the introduction of physical methods and principles, which have almost always produced marked advances, and frequently fundamental changes. Among the physical methods should be mentioned the balance, the spectroscopic methods of Bunsen and Kirchhoff, and the electrical methods, which, in the hands of Clausius and Arrhenius have led to the theory of electrolytic dissociation.

The introduction of physical principles has also accomplished much. Bertholet, Guldberg and Waage have explained the facts of chemical equilibrium, showing that a transformation only proceeds to a definite limit. They have introduced the idea of general attraction, and have shown how the active mass can be ascertained. Thomsen and Berthelot have attempted to apply the law of the conservation of work to chemical problems, and have developed the principle, which, however, does not always hold, that the heat evolved in a reaction is a measure of the affinity.

Through the united efforts of mathematicians, physicists and chemists, chemistry has, then, been placed upon a sure foundation. The second law of thermodynamics has been applied to chemical processes first by Horstmann, and then by Gibbs, Helmholtz, Duhem and others. This is, however, difficult for the chemist, since it involves a fairly good knowledge of mathematics and physics. It is, therefore, the problem of the physical chemists to give their well-established fundamental principles the simplest possible form. Something has been already accomplished.

1. The laws of dilute solutions, involving the conception of osmotic pressure, are just as simple as those of dilute gases, indeed, they are identical with them.

2. The heat evolved in a reaction determines the direction in which the equilibrium will be displaced by change in temperature. That which is formed with evolution of heat comes more and more to the front with decrease in temperature.

3. Affinity is closely connected with the conception of free work and is measured, not by the heat developed, but by the electrical work developed (electromotive force). Of these three principles, special stress is to be laid upon the importance of the last.

A very brief discussion of the *concrete* or *special sciences* follows. These include astronomy, meteorology, geography and geology.

Astronomy, by means of the spectroscope, has shown that in the spaces, so distant that it requires light many years to reach us, there is the same kind of matter as here on the earth. This includes iron, hydrogen and about twenty other elements, and these obey the same laws of reciprocal attraction as they do here on the earth. Astronomy

also calculates the history of the world in the future.

Geology gives us similar knowledge of the past, and shows that the world has not developed by sudden changes, as was formerly supposed, but that it has developed in accordance with the same laws which now reign.

HARRY C. JONES.

BUFO AGUA IN THE BERMUDAS.

ONE of the characteristics of the fauna of the Bermudas is the scarcity of terrestrial vertebrate forms. At present there is known but a single reptile (*Eumeces longirostris*) and a single amphibian (*Bufo agua* Daudin). In 1884 Jones and Goode ('Contributions to the Natural History of the Bermudas,' Bull. U. S. Nat. Mus.) recorded no amphibian. Heilprin ('The Bermudas,' Philadelphia, 1893, p. 84) says that in 1888 he saw a few individuals of *B. agua* in the salt marshes. As far as recorded, no amphibian had been known in the colony until the introduction of this species.

The history of its introduction, as gained from an interview with Captain Vesey in July, 1900, is as follows: Captain Nathaniel Vesey (at present a member of the Colonial Parliament from the parish of Devonshire) 'about fifteen years ago' engaged the master of a vessel plying between Hamilton and Demarara, British Guiana, to secure for him some of the Guianan toads, with a view to using them to catch garden insects. The toads were brought from Demarara to Hamilton, and were carried out to Devonshire by a native, who must have purloined some of the animals, for individuals were seen near the native's home (Tuckerstown), ten miles distant, soon afterward. Captain Vesey liberated 'about two dozen' individuals in his garden, where they thrived from the first and ate many insects.

From these two centers the animal has spread until it is common throughout the colony. In its search for moist places it often gets into the cisterns, fouling the water. This fact, together with its ugly appearance and the common opinion that it is venomous, has brought it into disfavor with the inhabitants.

The porosity of the rock permits no springs, streams or ponds in the islands. The only bodies of water are several brackish tidal ponds near the shore. There are some brackish marshes the salinity of which is less than that of the ponds, but which are by no means fresh. It is in these marshes that the animal breeds. It seems to have adopted these from necessity rather than from preference, for in Jamaica (Andrews) and in Brazil (Hensel) it spawns in fresh-water pools.

The eggs are extruded 'early in the spring,' according to local report, but this must be regarded as uncertain until we have better evidence. In Jamaica spawning is said to occur in October, and in Rio Grand do Sul, Brazil, in the middle of winter (June). In July, while at the Biological Station of New York University at Hamilton, I found large numbers of young, nine to fourteen millimeters long, in the grass and on the roads near the brackish marshes. They were especially abundant just after a shower.

Bufo agua is the largest living Anuran known. The largest specimen I have seen from Bermuda was collected by the New York University Expedition of 1898 and is now in the Zoological Museum at Columbia University. It measures 155 mm. from snout to vent, and weighs 960 gm. after having been two years in a four per cent. solution of formalin.

This toad is found in South and Central America and in the warmer parts of Mexico. It has not been included in the Neoarctic fauna by either Cope or Garman. I have found no record of it west of the Andes further south than Chimbo, Ecuador (about